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Utility of MODIS Aerosol Optical Depth for Estimating $PM_{2.5}$ Exposure in Environmental Public Health Surveillance

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As part of the National Environmental Public Health Tracking Network (EPHTN) the National Center for Environmental Health (NCEH) at the Centers for Disease Control and Prevention (CDC) is leading a project called Health and Environment Linked for Information Exchange (HELIX-Atlanta). The goal of developing the National Environmental Public Health Tracking Network is to improve the health of communities. Currently, few systems exist at the state or national level to concurrently track many of the exposures and health effects that might be associated with environmental hazards. An additional challenge is estimating exposure to environmental hazards such as particulate matter whose aerodynamic diameter is less than or equal to 2.5 micrometers ($PM_{2.5}$). HELIX-Atlanta's goal is to examine the feasibility of building an integrated electronic health and environmental data network in five counties of Metropolitan Atlanta, GA (Clayton, Cobb, DeKalb, Fulton, and Gwinnett counties). Under HELIX-Atlanta, pilot projects are being conducted to develop methods to characterize exposure; link health and environmental data; analyze the relationship between health and environmental factors; and communicate findings. NASA Marshall Space Flight Center (NASA/MSFC) is collaborating with CDC to combine NASA earth science satellite observations related to air quality and environmental monitoring data to model surface estimates of $PM_{2.5}$ concentrations that can be linked with clinic visits for asthma.

From 1999-2000 there were over 9,400 hospitalizations per year in Georgia with asthma as the primary diagnosis. The majority of these hospitalizations occurred in medical facilities in the five most populous Metro-Atlanta counties. Hospital charges resulting from asthma in Georgia are approximately $59 million dollars annually. There is evidence in the research literature that asthmatic persons are at increased risk of developing asthma exacerbations with exposure to environmental factors, including $PM_{2.5}$. Thus, HELIX-Atlanta is focusing on methods for characterizing population exposure to $PM_{2.5}$ for the Atlanta metropolitan area that could be used in on-going surveillance.

While use of the Air Quality System (AQS) $PM_{2.5}$ data alone could meet HELIX-Atlanta specifications, there are only five AQS sites in the Atlanta area, thus the spatial coverage is not ideal. Also, the AQS ground observations are made at time intervals ranging from one hour to six days leaving some temporal gaps. NASA Moderate Resolution Imaging Spectroradiometer (MODIS) satellite Aerosol Optical Depth (AOD) data have the potential for estimating daily ground level $PM_{2.5}$ at 10 km resolution over the metropolitan Atlanta area supplementing the AQS ground observations and filling their spatial and temporal gaps.

To estimate $PM_{2.5}$ from MODIS AOD observations, regression models were established separately for the Terra and Aqua MODIS data. First, MODIS AOD data from both Terra and Aqua satellites were obtained for the year 2003. Also, EPA's AQS ground-based $PM_{2.5}$ measurements were obtained for the Atlanta area. AOD data corresponding to the locations of the AQS sites were extracted from the MODIS data files. This was done by selecting any AOD observations located within a 10 x 10 km box centered at the site location. If more than one MODIS observation fell within the box, the values were averaged to give the AOD value for the site. Linear correlation coefficients were then calculated on a monthly basis for each satellite sensor, using all of the paired daily AOD - $PM_{2.5}$ observations for the month. This analysis revealed that the AOD - $PM_{2.5}$ relationship is generally weak during the cool season (October – March) and relatively strong during the warm season (April - September). This is consistent with the results shown in the research literature. Consequently, we grouped the data for April through September for each year and determined regression equations for each sensor. The obtained regression equations were applied to the Terra and Aqua MODIS AOD measurements on a 10 x 10 km grid across the region. After applying quality control and bias removal procedures to eliminate anomalous ground observations and remove biases in the satellite observations with respect to ground observations on a daily basis, the AQS ground-based $PM_{2.5}$ data were then merged with the Terra and Aqua MODIS $PM_{2.5}$ estimates to produce a spatial surface of estimated $PM_{2.5}$ for each day using a B-Spline surfacing technique. The estimated $PM_{2.5}$ results were then integrated with Health Maintenance Organization (HMO) asthma visits in Metro-Atlanta counties for further analysis that is ongoing.

This method of estimating $PM_{2.5}$ concentrations by merging MODIS remote sensing data with surface observations of $PM_{2.5}$ provides a more complete daily representation of $PM_{2.5}$ for the Atlanta metro area than either data set alone would allow. The applicability of this method for estimating $PM_{2.5}$ concentrations in other parts of the country and world merits further study.